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*An account of the course of the Tides at Tonqueen in
a Letter from Mr. Francis Davenport July 15.
1678. with the Theory of them, at the Barr of
Tonqueen, by the learned Edmund Halley Fellow
of the Royal Society.*

When the reported irregularity, of the *Ebbing and Flowing of the Sea* came first under my consideration at a distance, I was content to fancy that I had guessed aright in ascribing the occasion of it principally to the *Indraughts* and *outlets* of this *bay*, which as I Imagined might give (the different times of the year in respect of the *Monsoon's*, and the currents accordingly shifting with several other conceited coadjutant circumstances,) the most considerable share in the unusual course of the *Tides*, and that consequently it would scarce be possible to discover any constancy in them, if their regimen depended so much upon accidents and uncertainty's.

But during my continuance at *Batsha* I have observed such an order and constancy in the course of the *tides*, that notwithstanding I must needs confess it different from all that ever I observ'd in any other Port, yet not only from the coincidents of simular alterations on peculiar dayes of some particular *Moone's*, in different *monsoons* in respect of their increase and decrease, as well as from their keeping equal pace with the *Moon's* rising and setting in this *Horizon*, in respect of the duration of their *influx* and *reflux*, but also from that which seems to render them most irregular, viz. the constant falling back of the *flood* nearest 13 hours on every second day of the waters age and increase, so that at the end of 15 dayes there is an inversion of their motion in respect of their beginning to Flow and Ebb.

It is evident that they are regularly influenced though not reconcileable with a dependance on the *lunar* motion

tion so far as wholly to free the natural course from the interruption of some forreign intervening controulment.

Now for as much as it will be satisfactory enough for any mans benefit of the *tides* to know when the flood and ebb begins, and when there is the greatest and smallest influxes, without any nice discourse of the causes of their difference here, from those in other parts of the world, (a subject fitter for *Philosophers* then *Seamen*) I have here (to avoid overmuch tediousnes) entred only the result of my uninterrupted *observations*, of the *tides* dayly course, during my stay at *Batiba*, by which those *Commanders* who at this time of the year come before this *Barr*, may know when it will be most convenient to come over (supposing no *Pilate* goes off to bring them in) if they please to observe the following directions.

*Directions concerning the choice of time in respect of
the Tides for coming over the Bar.*

MY advice is, that upon the several following dayes of the *Moones* age in every particular month of the yeare, no *English Commander* should upon any occasion whatsoever adventure over this *Bar* unles he have a *Pilot* from the Shoare, who undertakes to bring him in, or that he hath only charge of some small *Bark* or *Junke*, that draws no more then 8 or 9 foot water.

In the $\frac{1}{7}$ *Moones*, from the $\frac{3}{17}$ to the $\frac{7}{21}$ dayes of the *moones* age exclusively

In the $\frac{2}{8}$ *moones*, from the $\frac{1}{14}$ to the $\frac{5}{18}$ dayes of the *moones* age exclusively,

and from the $\frac{2}{8}$ of the *moones* to the $\frac{3}{9}$ of the *moons* Excl.

- In the $\left\{ \begin{array}{l} 3 \\ 9 \end{array} \right\}$ moones, from the $\left\{ \begin{array}{l} 11 \\ 25 \end{array} \right\}$ to the $\left\{ \begin{array}{l} 15 \\ 29 \end{array} \right\}$ dayes of the moones age exclusively,
- In the $\left\{ \begin{array}{l} 4 \\ 10 \end{array} \right\}$ moones from the $\left\{ \begin{array}{l} 9 \\ 23 \end{array} \right\}$ to the $\left\{ \begin{array}{l} 13 \\ 27 \end{array} \right\}$ dayes of the moones age exclusively,
- In the $\left\{ \begin{array}{l} 5 \\ 11 \end{array} \right\}$ moones from the $\left\{ \begin{array}{l} 7 \\ 21 \end{array} \right\}$ to the $\left\{ \begin{array}{l} 11 \\ 25 \end{array} \right\}$ dayes of the moones age exclusively,
- In the $\left\{ \begin{array}{l} 6 \\ 12 \end{array} \right\}$ moones from the $\left\{ \begin{array}{l} 5 \\ 19 \end{array} \right\}$ to the $\left\{ \begin{array}{l} 9 \\ 23 \end{array} \right\}$ dayes of the moones age exclusively.

And excepting on these six dayes above mention'd in every respective *moone*, he may safely adventure over the *Bar* any day provided allways that he mistake not the time of the *tide*, but come over at half *Flood* or better, though he may take notice, that the best *Tides* will be about six or seven dayes after the waters first begining to increase, and the first dayes of the waters increase are

In the $\left\{ \begin{array}{l} 1 \\ 7 \end{array} \right\}$ moones on the	$\left\{ \begin{array}{l} 19 \\ 3 \end{array} \right\}$ dayes.	of the <i>Moones</i> age.
In the $\left\{ \begin{array}{l} 2 \\ 8 \end{array} \right\}$ moones on the	$\left\{ \begin{array}{l} 16 \\ 29 \end{array} \right\}$ dayes.	
In the $\left\{ \begin{array}{l} 3 \\ 9 \end{array} \right\}$ moones on the	$\left\{ \begin{array}{l} 13 \\ 27 \end{array} \right\}$ dayes.	
In the $\left\{ \begin{array}{l} 4 \\ 10 \end{array} \right\}$ moone. on the	$\left\{ \begin{array}{l} 11 \\ 25 \end{array} \right\}$ dayes.	
In the $\left\{ \begin{array}{l} 5 \\ 11 \end{array} \right\}$ moones on the	$\left\{ \begin{array}{l} 9 \\ 23 \end{array} \right\}$ dayes.	
In the $\left\{ \begin{array}{l} 6 \\ 12 \end{array} \right\}$ moones on the	$\left\{ \begin{array}{l} 7 \\ 21 \end{array} \right\}$ dayes.	

It is needless to take notice in what hours the waters increase begins, because the regular course of the *Tides* is not from thence commenced, in respect of the time of Flowing and Ebbing.

The *Bar* it selfe being about a Mile and half in Length, and no where except in its first entrance exceeding half a Mile in Breadth, is very even, but yet affords considerably differing soundings in the same Age and time of the tides, according to the season of the *Year*, and which seems to be somewhat strange, hath the highest *Tides* in the *Northerly Monson*, as I have been informed by those who are seemingly best able to give an account thereof: and I must needs say, that the tryal I now made on the *Bar* did accord with what I understood from several of the *Fishermen* and others as to this *Month*, which induced me to enter this Information, that coming over at half flood (except on the dayes aforementioned as Dangerous to come over in) there will be found according to the age of the *Tides*.

In the	3	Moones from 16 to 21 feet water.
	4	
	5	
In the	6	
	7	Moones from 19 to 24 feet
	8	
In the	9	
	10	Moones from 21 to 27 feet
	11	
In the	12	
	1	Moones from 14 to 22 feet.
	2	

Always the higher the *Flood* the Lower the *Ebb*, so that according to the strength of the *Tides* at Low water, the soundings are from 6 to 13 feet.

N.B. This *Bar* of *Tynking* is about 110 degrees of *Longitude* to the East of *London*, and in *Latitude* 50. 50.

On

On the first and second dayes of the waters increase the *influxes* are very small and uncertain, but afterwards the *Tides* for 13 dayes are constant in their course, one flood and one ebb being compleated in 24 hours time, equally sharing the space of a *Lunar* circuituion of the Earth between them, and every *flood* beginning nearest $\frac{3}{4}$ of an hour later then the *precedent flood*, and also considerably increasing in the height of the *tide* every day from the 3^d unto the 6th and 7th dayes of the waters age, on which two dayes the *flood* runs very high, but on the 8th day (which may be accounted the last of the *spring tides*, the waters begin gradually to decrease again, retaining the same orderly difference of time in each *tide*, until the next following first day of the waters increase, when during two dayes unsetlednes, there is a shifting of the *tides* in respect of the beginning of the *flood* and *ebb*, after which said shifting, a constancy in their inverted course, is again retained in the above mentioned order for 13 dayes following, as for *Example*.

On the 25 and 26 dayes of the 4th moone (4th and 5th of June 1678) in the latter end of *Aries* being the first dayes of the waters increase, the *influxes* were very small (there happening on the 26th a falling back of the *tides* about 13 hours) but from the 27th (June 6. 78.) which was the 3^d day of the waters increase after the last quarter; unto the 9th day of the 5th moones age, (June 18. 1678) in \cong 20, I noted a very constant course in the *tides*, every *flood* begining with the rising of the *moone* and ending at its setting, the following *ebb* in like manner continuing during the time of the *moones* absence from this *hemi/sphere*. But on the said 9th day of the 5th moones age (June 18. 1678) being the first day of the waters increase, their motion was scarcely perceptible; on the 10th day there was another falling back of the *tides* neareit 13 hours, and on the 11th day, (which was the 3^d day of the waters increase, after the first quarter of the *moones* age) the *flood* having (as I said) shifted the preceding

ceding day, took its turne to begin at the *moones* setting and end at its rising, and accordingly the tides successively following assumed & kept a conftant regularity the *tides* being at highest the 16th of the *moone*, (1678. June 24. ¶ in middle of 7) which was the seventh of the waters age, until the 23^d of the said *moones* age (July 1. 1678.) on which (being the first day of the waters increase) the influx was again scarcely discernable for its smallness.

On the 24th day the *tides* fall back (as I had found it twice before to have done on the same dayes of the waters age,) nearest 13 hours by which meanes the *flood* on the 25th day (which was the 3^d day of the waters increase after the last quarter of the *moone*) now again commenced with the riseing *moone*, whereby it hath fallen out allwayes to be high water between *noone* and the following *midnight* every day during my stay here. (¶ last quarter 22 dayes, ¶ first quarter 8 dayes.)

So that it may pass into a *Corollary* viz. In the 4th 5th and 6th changes of the *moone* from the 3^d day of the waters age after the last quarter, to the 3^d day of the waters age after the first quarter of the following *moone*, the water begins to *flow* when the *moone* riseth, and to *ebb* again when it setteth in the *Horizon*, and the contrary to the 3^d day of *their* age after the last quarter, exclud-
ing allwayes their motion on the 2 first dayes of the waters increase, because of its smallness and uncertainty.

I am inform'd by the *inhabitants* here abouts, that this may hold for a *rule* from the 2^d to the end of the 7th *moone* and that the *converse* thereof holds true in the other six months of the year, viz. from the 8th to the end of the first *moone*, according to which the *tides* will fall out to be at the highest in the evening for 6 months successively, and the other half year in the *morning*, that is to say between *midnight* and the following *moones*, and though I cannot aver the truth of it, yet I find that the *tide*

tide last year in the 11th moone, which occasionally upon the Ship *Eagles* departure hence, I took some notice of, and entred in the close of my *Sea journal*, did fall out not disagreeing with what they affirme, and I am yet the rather induc'd to believe that in every *annual revolution* there may be such a constancy in this different motion of the tide appropriated to each moiety of the year, because, that dureing my dayes stay at *Batba*; I have found the *predictions* of the *natives* confirmed by my owne *observations* of the tides falling out to be high water alwayes between *noone* and the succeeding *midnight* occasioned by the aforesaid falling back at the end of 15 dayes; so that on every 3d day of the waters increase, the *flood* begins at the hour whereon the day before it ended.

To prevent mistakes in the accompt of the *moones*, though the difference of *meridians* between this *place* and *London*, together with the different beginning of their *natural day* in their accompts here, from that of ours, and some imperfections from which their *Astronomical observations* are not free, may occasion a disagreement between our accompt and theirs, of the *moones* age, yet it will never be so considerable as to occasion any sensible, at least dangerous *error* in the above mentioned reckoning of the *tides*, provided the number of the moneth be not mistaken.

Wherefore it may be sufficient to informe those who use this *Port*, that the first change of the *moone* after the 15th day of *January* old stile, is reckoned for the beginning of the year, and that *moone* being accompted the first, the rest follow in order until the expiration of the 12th which compleats their *year*, alwayes except only in their *leap years*, and then they have 13 *moones*, takeing in one extraordinary to make up the deficiency of the *moones* *epact* in their accompt, in which year the first day of their new yeares *moone* falls out before the said 15th of *January*, as it did this year upon the 12th being *leap yeare* with them,

them, so that they reckoned two months for one this
yeare, (that is to say the 2d and 3d *moones* after their
newyears day) they called 2d *moones*, for otherwayes this
present *moone* which changed in *July* (the 8th) woul'd have
been the 7th, whereas now they count it but the 6th
moone, and accordingly do the *tides* fall out, but this *leap*
yeare being now past the first *moone* in the yeare must be
reckoned to begin on the change next following the 15th
of *January*, and all the other changes counted successively
as before said until the intervention of another *leap*
yeare.

Observations

A Theory of the Tides at the Bar of Tunking by the Learned Mr. Edm. Halley, Fellow of the Royal Society.

The effect of the *Moon* upon the *waters*, in the production of the *tides* in this *port* of *Tunking*, is the more wonderful and surprizing, in that it seemes different in all its circumstances from the *general rule*, whereby the motion of the *Sea* is regulated, in all other parts of the world I have yet heard of. For first, each *flux* is of about 12 hours duration, and its correspondent *reflux*, as long, so that there is but one *high water* in 24 hours. Then there are in each month, two *intermissions* of the *Tides*, about 14 dayes asunder when there is no sensible *flood* or rising of the *waters* to be observed; but the *Sea* is in a manner *stagnant*. Thirdly, that the increase of the *Water* has its 14 days *period*, between the aforesaid *intermissions*; and at 7 days end, makes the highest *tides*, from which time the *water* again gradually abates, and the *flood* is weaker till it comes to a *stagnation*, both *increase* and *decrease* observing the same *rule* in being exceeding *slow* in their begining and end, and *swift* in the middle. Lastly, (and which is most odd) the *rising Moon* in the one half of each *month* makes *high water*, and the *setting moone* in the other half. These particulars considered together with the *Tables* shewing the days of the *waters stagnation*, in each moneth, gave me a light into the secret of this strange appearance, so as to be able to bring the hitherto unaccountable irregularity of these *Tides* to a certain rule. And first it appears by the latter of the two *Tables*, that the *intermissions* of the *Tides* happen nearly upon those days, that the *moon* enters the signs of *Aries* and *Libra*; or passes the *Equinoctial*; which divides the *Moons* course nearly into two equal parts, as well as the *Suns*, and from hence it follows that the *Tropical*

tical Moones in ♈ and ♉, are these which occasion the greatest flux and reflux; and for the rule of the change of the time of *high Water*, which Mr. *Davenport* calls a falling back of the *Tides*, the example he hath given us, lets us know, that the ♈ in *Northern signs*, brings in the *flood* whilst she is above the *Horizon*, so as to make *high water* at her setting, and on the contrary that whilst shee is in *Southern signs*, it flows all the time the *moon* is below the *Horizon*, and so make *high water* at her *rising*. But it is to be obserued that though the *Moon* passe swiftly, from *South* to *North* when she is in or near ♈, and from *North* to *South* when in or near *Libra*; yet the *motion* of the *Sea* which is the cause of this *tide*, is scarce discernable for 3 or 4 days, when the *Moon* passe the said *Equinoctial* points; whence it appears that though the *declination* of ♈, or her distance from the *Equinoctial*, be that whereby these *Tides* are regulated, yet the increase and decrease of the *water* is by no meanes proportionate to that of the *declination of Luna*, that changing swiftly, where the increase of the water is obserued to be most slow. It seemis therefore, and I propose it as a probable conjecture, that the *increase* of the *waters* should be allways proportionate to the *Versed signes* of the doubled distances of the *Moon* from the *Equinoctial* points; Upon which *Hypothesis* Figure 9. will give an elegant *Synopsis* of the whole matter. Let *AB* be the bottom of the *Bar* of *Tunking*; *CD* a *perpendicular* thereto, whereon to measure the severall depths of the water; *Cv*, *Cz* the *mean depth*, which is that whereat the water is stagnant upon the *moons* being upon the *Equinoctial* points, being commonly about 15 feet: *Cz occid*, the *high water mark* when the *Moon* is in ♈ or ♉ being about 24 foot. *Cv occid* the *hight* of the *Low water mark* when the *Moon* is in ♈ or ♉, being about 6 foot; so that the greatest rise of the *Water* on the *Tropical Moons* will be about 18 foot; then dividing *v* ♈ and ♉ into two equal parts in *EF*, on those two points, as *Centers*, describe the 2 *Circles*, each of whose *Radii*, are four

four feet and a half, which being kept between the *Compasses*, naturally divide the said *Circles* in the points $\textcircled{8}\textcircled{1}\textcircled{2}\textcircled{3}\textcircled{4}\textcircled{5}\textcircled{6}\textcircled{7}\textcircled{8}$ &c. through the which points if you draw lines parallel to the base A B they shall cut the *perpendicular* C D, in the hights of the *high* and *Low water* marks, which will be at the entrance of the *Moon* into the said *signs*. So the greatest depth of the *high water*, when the *Moon* enters $\textcircled{8}, \textcircled{9}, \textcircled{10}, \textcircled{11}$, is but $17\frac{1}{4}$ feet, and the least at *Low water* $12\frac{1}{4}$ feet: but when she Enters $\textcircled{1}, \textcircled{2}, \textcircled{3}, \textcircled{4}, \textcircled{5}$, the *high-water* depth is $21\frac{1}{4}$ feet, the *Low-water* but $8\frac{1}{4}$ feet; as appears by the *figure*. And this Hypothesi's not only agrees with all that Mr. *Davenport* hath observed himself, or collected from the *Natives*, but hath been found to hold true since in the year 1682 by the Ingenious Capt. *Knox*, in his *Voyage* to this *port*; so that there is no room to doubt of the truth thereof: By this *method* may the time and hight of the *Tides* be with sufficient certainty computed, but to *philosophize* theron, and to attempt to assign a reason, why the *Moon* should in so particular a manner influence the *waters* in this one place, is a task too hard for my undertaking, especially when I consider how little we have been able to establish a *Genuine* and *satisfactory Theory* of the *Tides*, found upon our own *Coasts*, of which wee have had so long *Experience*. It would be however a very acceptable thing if some curious *Navigators* would inform us, what *tides* or *Currents* are found at *Macao*, *Quemoy*, and other places on the *Coast of China* and on *Formosa*; it being most probable that this *flood* cometh out of the *North East*, a longst the *Coast of China*, for that the *Northerly Moonsoon* is found to occasion the highest *spring-tides*. There is yet another thing well worth Inquiry, that seeing that this motion of the *Sea* is more or less as the *Moon* is farther from or nearer to the *Equinoctiall*, it is not unlikely, that some years may have much higher *Spring-tides* than others, according to the Various *Obliquity* of the *Moons orbite* to the *Equinoctiall*, for when the *ascending Node* is in *V*, (as it was anno 1671 and will be anno 1690)

the *Moon* in ♉ and ♈ deviates from the *Equator* full $28\frac{1}{2}$ degrees; and but $18\frac{1}{2}$ degrees, when the same *Node* is in *Libra*, as it was anno 1680; and I recommend as a very ulefull *Querie*, for such as for the future shall use this *Port*, to examine whether the *Tides* are not in some years more *Vigorous* than in others, and particularly in the years but now mentioned; as likewise if there have been any *Inundations* occasioned by an extraordinary *flux* of the *Sea*, in what years the said *Inundations* have happened.

Defectus.